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(54)Title of the Invention: PHOTOELECTRIC CONVERSION DEVICE

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Specification

1. Title of the Invention

Photoelectric Conversion Device

2. Claims:

1. A photoelectric conversion device comprising a substrate partly having an insulating substrate or an insulating layer and a semiconductor layer having N region, i region, and P region on one plane thereon, characterized in that: (a) the semiconductor layer is formed of crystalline silicon; and (b) the surface of the substrate corresponding to at least the i-region semiconductor layer is roughened and the relationship between the surface roughness (cm) and the crystal grain diameter (cm) is as follows:

(surface roughness) × (crystal grain diameter) ≤ 10^{-5} (cm^2)

3. Detailed Description of the Invention

[Technical Field of the Invention]

The present invention relates to a photoelectric conversion device for faxes, OCRs, and copying machines.

[Prior Art]

Hitherto, since photoelectric conversion devices could not be manufactured in the same process as that of high-integrated thin-film transistors (TFTs) using an IC or Si, it was necessary to produce anew a photodiode or a phototransistor for photoelectric conversion after a TFT by the IC processing has been manufactured. This is a leading cause of an increase in costs.

In addition, while thin-film photodiodes or phototransistors using a-si:H (amorphous silicon) have been in the mainstream, this is because the a-Si:H has a relatively high absorption coefficient for light as compared with crystalline Si suitable for the manufacture of a TFT, even a relatively thin film can efficiently absorb light. If crystalline Si (poly-Si or single-crystal Si) capable of forming a thin film suitable for the manufacture of a TFT is used in place of this a-Si:H, it is necessary to increase the thickness thereof by one to two orders of magnitude because the Poly-Si and the single crystal Si have a light absorption coefficient lower than a-Si or the a-Si:H by one to two orders of magnitude, causing an obstacle to downsizing of a thin film.

[Object]

It is an object of the present invention to manufacture a photoelectric conversion device equipped with a TFT in the same process as an IC manufacturing process, the obtained device having high reliability.

[Configuration]

The present invention is a photoelectric conversion device comprising a substrate partly having an insulating substrate or an insulating layer and a semiconductor layer having N region, i region, and P region on one

plane thereon, characterized in that: (a) the semiconductor layer is formed of crystalline Si; and (b) the surface of the substrate corresponding to at least the i-region semiconductor layer is roughened and the relationship between the surface roughness (cm) and the crystal grain diameter (cm) is as follows:

(surface roughness) × (crystal grain diameter) ≤ 10^{-5} (cm^2)

Where the substrate surface roughness indicates the depth between the peaks and valleys of the substrate.

In this manner, the roughness, that is, a rough surface, that is, unevenness is formed on the surface of the substrate, and thus light absorption as high as that of a-Si could be realized even when crystalline Si is used as a semiconductor layer.

Among insulating substrates are quartz, glass, and ceramics, and among noninsulating substrates are a silicon wafer and metal, wherein among insulating thin films used in such cases are a thermally oxidized film and a nitride film.

Although there is no limitation on a method of forming unevenness on the substrate surface, normally it is formed by dry etching. In general, d is from 10^{-2} to 10^{-4} cm, preferably, from 10^{-2} to 5×10^{-5} cm. In the case of dry etching, d can arbitrarily be adjusted by varying

the pressure of etching gas. For example, when CF_4 is used as etching gas, the relationship between its use pressure and surface roughness becomes as shown in Fig. 1. R is normally from 10^{-2} to 10^{-4} cm, preferably, from 5×10^{-6} to 3×10^{-5} cm.

A typical model of a photoelectric conversion device of the present invention is shown in Fig. 2 in which a crystalline Si layer is formed on the roughened substrate surface as described above.

In Fig. 2, reference numeral 1 denotes an insulating substrate, reference numeral 2 denotes a crystalline Si layer, and reference numeral 3 denotes an uneven portion formed at part of the insulating substrate. The crystalline Si layer 2 is formed into one plane, wherein the thickness thereof is normally from 1000 Å to 5 μm, preferably, from 2000 to 5000 Å, of which reference numeral 2-1 indicates P region, reference numeral 2-2 indicates i region, and reference numeral 2-3 indicates n region. Those with such a configuration are useful as a photodiode.

The present invention can also be used as a phototransistor by constituting each region of the aforesaid crystalline Si into N-i-N, N-P-N, P-i-P, P-N-P, and so on.

Fig. 3G shows an example of devices in which a

photoelectric transducer and a TFT using a Poly-Si, which is a drive circuit therefor, are integrated with each other by using the technique of the present invention. Reference numeral 1 denotes an insulating substrate; reference numeral 2-1 denotes N region formed in the Poly-Si layer; reference numeral 2-2 denotes i region formed in the Poly-Si layer; reference numeral 2-3 denotes P region formed in the Poly-Si layer; reference numeral 3 denotes a rough surface formed on the insulating substrate; reference numerals 4 and 5 each denote an SiO_2 layer; and reference numeral 6 denotes a conductor such as metal, in which the right side functions as a photoelectric transducer and the left side functions as a TFT serving as a drive circuit therefor.

[Example]

(a) The insulating substrate 1 made of quartz was exposed in an atmosphere of $CF_4$4 plasma torr for 10 minutes, whereby the substrate surface was roughened. At that time, d was 1000 Å. (See Fig. 3A)

(b) Poly-Si layers having a thickness of about 3000 Å were formed at 600°C at necessary portions on the substrate processed in (a) step by LPCVD method using SiH_4 of 100 %. The crystal grain diameter at that time was about 500 Å. (See Fig. 3B)

(c) Subsequently, the Poly-Si layers were thermally

oxidized to form SiO_2 layers having a thickness of about 1000 Å on the surface of the Poly-Si layers. (See Fig. 3C) The thermal oxidization was performed at 1000° C using dried O_2.

(d) In order to form the N regions, portions except for portions desired for the N regions were masked by an arbitrary method, and vapor diffusion by BBr_3 was performed. Consequently, portions indicated by 2-1 were formed into N regions shown in Fig. 3D.

(e) The masks were removed and, after portions except for portions desired for the P regions had been masked, vapor diffusion by $POCl_3$ was performed. Consequently, portions indicated by 2-3 were formed into P regions shown in Fig. 3D.

(f) An insulating layer 5 formed of SiO_2 was formed by an ordinary method. (See Fig. 3F)

(g) Finally, holes were formed in necessary portions of the SiO_2 layer 5, in which metallic wiring 6 was performed.

Of course, the diffusion of impurities can sufficiently be performed by methods, such as ion injection, other than the above-described method.

[Advantages of the Invention]

Since the present invention has the above configuration as a photoelectric conversion device, a photoelectric transducer and a TFT can simultaneously be

manufactured in the same process, thus providing such advantages as low cost, high process yield, high reliability, and high integration.

4. Brief Description of the Drawings

Fig. 1 shows the relationship between the surface roughness of a quartz substrate and the gas pressure of CF_4; Fig. 2 is a sectional view of a model configuration of a photoelectric conversion device of the present invention; and Fig. 3 shows manufacturing process drawings and the product according to an embodiment of the present invention.

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[Fig. 1]

1: SURFACE ROUGHNESS

2: PRESSURE OF CF_4 (torr)

3: QUARTZ

[Fig. 3]

1: PHOTOELECTRIC TRANSDUCER